

DESCRIPTION  
BALANCED SPLITTER

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Technical Field

The present invention relates to a balanced splitter, in particular, a balanced splitter for use in mobile communication devices or the like.

Background Art

With the trend toward higher signal frequency, an increasing number of communication devices use a balanced signal for the purpose of improved anti-noise characteristics and the like. For this reason, there is a need for an unbalanced/balanced converter for converting an unbalanced signal into a balanced signal. Further, there is also a need for a splitter for splitting a signal into two depending on the intended applications. Accordingly, there is a growing need for a component combining the functions of both the converter and the splitter, that is, an "unbalanced output/balanced input splitter (balanced splitter)" for splitting a single unbalanced signal into two balanced signals.

As shown in Fig. 13, an unbalanced output/balanced input splitter (balanced splitter) 1 is obtained by combining one unbalanced output/balanced input splitter (a generally known splitter) 2 that splits an unbalanced signal input from an unbalanced terminal 5 into two, and two unbalanced/balanced converters (so-called baluns) 3, 4 that convert each of the two split unbalanced signals into a balanced signal. The balanced signals exiting the unbalanced/balanced converters 3, 4 are output from first balanced terminals 6a, 6b and second balanced terminals 7a, 7b, respectively.

Alternatively, the unbalanced output/balanced input splitter (balanced splitter) is obtained by combining one unbalanced/balanced converter (so-called balun), which converts an unbalanced signal into

a balanced signal, with one balanced input/balanced output splitter that splits the one balanced signal output from the unbalanced/balanced converter into two.

A known unbalanced/balanced converters include those described in Patent Document 1 and Patent Document 2. Based on of Patent Document 1 and Patent Document 2, the unbalanced output/balanced input splitter (balanced splitter) 1 shown in the block circuit diagram of Fig. 13 is illustrated in more detail in the electric circuit diagram of Fig. 14. The balanced splitter 1 is composed of ten  $1/4$  wavelength strip lines 11 to 20 and one resistor R.

However, when the balanced splitter 1 is composed by combining the splitter 2 and the baluns 3, 4, each of which are separate components, a problem in that the number of components increases arises. Further, as shown in Fig. 14, when those separate components 2 to 4 are simply integrated into one component, the internal circuit configuration of the component becomes rather complex, causes leading to such problems as high manufacturing cost and large insertion loss.

Patent Document 1: JP 2001-94316 A

Patent Document 2: JP 2001-168607 A

#### Disclosure of Invention

#### Problem to be Solved by the Invention

The purpose of present invention provides a balanced splitter having a simple circuit configuration and achieving miniaturization.

#### Means for Solving the Problem

In order to achieve the above-mentioned purpose, a balanced splitter according to the present invention includes: an unbalanced line including a first strip line and a second strip line that are connected in series; an unbalanced terminal electrically connected to the first strip line of the unbalanced line; a first balanced line including a third strip line electromagnetically coupled to the first strip line, and a fourth strip line electromagnetically coupled to the

second strip line; a first balanced terminal including two terminals, one and the other of the two terminals being electrically connected to the third strip line and the fourth strip line of the first balanced line, respectively; a second balanced line including a fifth strip line electromagnetically coupled to the first strip line, and a sixth strip line electromagnetically coupled to the second strip line; a second balanced terminal including two terminals, one and the other of the two terminals being electrically connected to the fifth strip line and the sixth strip line of the second balanced line, respectively; a first resistor electrically connected between the first balanced terminal connected to the third strip line and the second balanced terminal connected to the fifth strip line; and a second resistor electrically connected between the first balanced terminal connected to the fourth strip line and the second balanced terminal connected to the sixth strip line.

More specifically, a balanced splitter according to the present invention includes: a first strip line having one end and the other end; a second strip line having one end and the other end, the other end being electrically connected to the other end of the first strip line; an unbalanced terminal electrically connected to the one end of the first strip line; a third strip line having one end and the other end, the one end being electrically connected to a ground; a fourth strip line having one end and the other end, the one end being electrically connected to the ground; a first balanced terminal including two terminals, one and the other of the two terminals being electrically connected to the other end of the third strip line and the other end of the fourth strip line, respectively; a fifth strip line having one end and the other end, the one end being electrically connected to the ground; a sixth strip line having one end and the other end, the one end being electrically connected to the ground; a second balanced terminal including two terminals, one and the other of

the two terminals being electrically connected to the other end of the fifth strip line and the other end of the sixth strip line, respectively; a first resistor electrically connected between the other end of the third strip line and the other end of the fifth strip line; and a second resistor electrically connected between the other end of the fourth strip line and the other end of the sixth strip line, wherein: the one end of the second strip line is an open end; and the first strip line and the third strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, the first strip line and the fifth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, the second strip line and the fourth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, and the second strip line and the sixth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other.

Alternatively, a balanced splitter according to the present invention includes: a first strip line having one end and the other end; a second strip line having one end and the other end, the other end being electrically connected to the other end of the first strip line; an unbalanced terminal electrically connected to the one end of the first strip line; a third strip line having one end and the other end, the other end being electrically connected to a ground; a fourth strip line having one end and the other end, the other end being electrically connected to the ground; a first balanced terminal including two terminals, one and the other of the two terminals being electrically connected to the one end of the third strip line and the one end of the fourth strip line, respectively; a fifth strip line having one end and the other end, the other end being electrically connected to the ground; a sixth strip line having one end and the

other end, the other end being electrically connected to the ground; a second balanced terminal including two terminals, one and the other of the two terminals being electrically connected to the one end of the fifth strip line and the one end of the sixth strip line, respectively; a first resistor electrically connected between the one end of the third strip line and the one end of the fifth strip line; and a second resistor electrically connected between the one end of the fourth strip line and the one end of the sixth strip line, wherein: the one end of the second strip line is electrically connected to the ground; and the first strip line and the third strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, the first strip line and the fifth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, the second strip line and the fourth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other, and the second strip line and the sixth strip line are electromagnetically coupled to each other such that the one ends and the other ends thereof are opposed to each other.

Herein, the first, second, third, fourth, fifth, and the sixth strip lines are  $1/4$  wavelength strip lines.

Further, a resistance value of the first resistor and a resistance value of the second resistor are each  $1/2$  of the sum of a balanced line characteristic impedance value of the first balanced terminal and a balanced line characteristic impedance value of the second balanced terminal.

According to the above-described construction, an unbalanced signal entering from the unbalanced terminal propagates by way of the first strip line and the second strip line. Then, through electromagnetic coupling with the third strip line and the fifth strip

line in the first strip line, and through electromagnetic coupling with the fourth strip line and the sixth strip line in the second strip line, the one unbalanced signal is converted into two balanced signals, and those balanced signals are extracted from the first balanced terminal and the second balanced terminal.

Further, in a balanced splitter according to the present invention, first, second, third, fourth, fifth, and sixth strip lines, and ground electrodes are laminated on top of one another through the intermediation of dielectric layers to form a laminate, and an unbalanced terminal, a first balanced terminal and a second balanced terminal, and a ground terminal are provided to a surface of the laminate, the first balanced terminal and the second balanced terminal each including two terminals; the unbalanced terminal is electrically connected to the first strip line of an unbalanced line including the first strip line and the second strip line that are connected in series; one and the other of the first balanced terminals are electrically connected to the third strip line and the fourth strip line of a first balanced line, respectively, the first balanced line including the third strip line electromagnetically coupled to the first strip line, and the fourth strip line electromagnetically coupled to the second strip line; one and the other of the second balanced terminals are electrically connected to the fifth strip line and the sixth strip line of a second balanced line, respectively, the second balanced line including the fifth strip line electromagnetically coupled to the first strip line, and the sixth strip line electromagnetically coupled to the second strip line; a first resistor is electrically connected between the first balanced terminal connected to the third strip line and the second balanced terminal connected to the fifth strip line; and a second resistor is electrically connected between the first balanced terminal connected to the fourth strip line and the second balanced terminal connected to

the sixth strip line. With the above-described construction, a laminated balanced splitter can be easily obtained.

A construction may be adopted in which, with respect to a laminating direction of the dielectric layers, the ground electrodes are respectively arranged in an upper layer portion, a middle layer portion, and a lower layer portion of the laminate, the first, third, and fifth strip lines are arranged between the ground electrode in the upper layer portion and the ground electrode in the middle layer portion, and the second, fourth, and sixth strip lines are arranged between the ground electrode in the middle layer portion and the ground electrode in the lower layer portion. Conversely, a construction may also be adopted in which the second, fourth, and sixth strip lines are arranged between the ground electrode in the upper layer portion and the ground layer in the middle layer portion, and the first, third, and fifth strip lines are arranged between the ground electrode in the middle layer portion and the ground electrode in the lower layer portion.

Further, the surface of the laminate may be provided with an external terminal for electrically connecting one of the first resistor and the second resistor, the first resistor and the second resistor being arranged on the surface of the laminate.

#### Advantages

According to the present invention, the internal circuit configuration of the components is simplified, thereby making it possible to obtain a compact balanced splitter having low manufacturing cost and small insertion loss.

#### Brief Description of the Drawings

Fig. 1 is a block diagram of a balanced splitter according to a first embodiment of the present invention.

Fig. 2 is a block diagram of a balanced splitter according to a second embodiment of the present invention.

Fig. 3 is an exploded perspective view of a balanced splitter according to a third embodiment of the present invention.

Fig. 4 is a perspective exterior view of the balanced splitter shown in Fig. 3.

Fig. 5 is an exploded perspective view of a balanced splitter according to a fourth embodiment of the present invention.

Fig. 6 is a perspective exterior view of the balanced splitter shown in Fig. 5.

Fig. 7 is an exploded perspective view of a balanced splitter according to a fifth embodiment of the present invention.

Fig. 8 is a perspective exterior view of the balanced splitter shown in Fig. 7.

Fig. 9 is an exploded perspective view of a balanced splitter according to another fifth embodiment of the present invention.

Fig. 10 is a perspective exterior view of the balanced splitter shown in Fig. 9.

Fig. 11 is an exploded perspective view of a balanced splitter according to a sixth embodiment of the present invention.

Fig. 12 is a perspective exterior view of the balanced splitter shown in Fig. 11.

Fig. 13 is a block diagram of a conventional balanced splitter.

Fig. 14 is an electric circuit diagram of the balanced splitter shown in Fig. 13.

#### Best Mode for Carrying Out the Invention

Hereinbelow, embodiments of a balanced splitter according to the present invention will be described with reference to the accompanying drawings.

#### EMBODIMENT 1 (see Fig. 1)

As shown in Fig. 1, a balanced splitter 21 has 1/4 strip lines 31, 32, 33, 34, 35, 36. Each of the strip lines 31, 32, 33, 34, 35, 36 has one end 31a, 32a, 33a, 34a, 35a, 36a and another end 31b, 32b, 33b,



34b, 35b, 36b, respectively. The one end 31a of the strip line 31 is electrically connected to an unbalanced terminal 22, and the other end thereof 31b is electrically connected to the other end 32b of the strip line 32. The one end 32a of the strip line 32 is an open end. The one end 33a of the strip line 33 is grounded, and the other end 33b thereof is electrically connected to a first balanced terminal 23a. The one end 34a of the strip line 34 is grounded, and the other end 34b thereof is electrically connected to a first balanced terminal 23b. The one end 35a of the strip line 35 is grounded, and the other end 35b thereof is electrically connected to a second balanced terminal 24a. The one end 36a of the strip line 36 is grounded, and the other end 36b thereof is electrically connected to a second balanced terminal 24b.

Further, the one and other ends of each of the strip lines 31, 33 are opposed to each other so that the strip lines 31, 33 become electrically coupled, thereby forming a coupler. Further, the one and other ends of each of the strip lines 32, 34 are opposed to each other so that the strip lines 32, 34 become electrically coupled, thereby forming a coupler.

Likewise, the one and other ends of each of the strip lines 31, 35 are opposed to each other for electromagnetic coupling, thereby forming a coupler. Further, the one and other ends of each of the strip lines 32, 36 are opposed to each other for electromagnetic coupling, thereby forming a coupler.

The strip lines 31 and 32 are connected in series to form an unbalanced line, the strip lines 33 and 34 form a first balanced line, and the strip lines 35 and 36 form a second balanced line.

Further, resistors R1 and R2 are electrically connected between the first balanced terminal 23a and the second balanced terminal 24a, and between the first balanced terminal 23b and the second balanced terminal 24b, respectively. The values of the resistors R1, R2 are

respectively designed to be  $1/2$  of the sum of the balanced line characteristic impedance value of the first balanced terminal 23a, 23b and the balanced line characteristic impedance value of the second balanced terminal 24a, 24b.

The balanced splitter 21 is an "unbalanced input/balanced output splitter" for splitting a single unbalanced signal into two balanced signals. That is, an unbalanced signal input from the unbalanced terminal 22 propagates by way of the strip line 31 and the strip line 32. Then, the strip lines 31 becomes electrically coupled through electromagnetic coupling among the strip lines 33, 35, and the strip lines 32 become electrically coupled the strip lines 34, 36, the single unbalanced signal is converted into two balanced signals, which are extracted from the first balanced terminals 23a, 23b and the second balanced terminals 24a, 24b.

In contrast to the conventional balanced splitter 1 shown in Fig. 13, which involves an increase in overall insertion loss due to the insertion loss of the splitter 2 and the insertion losses of the baluns 3, 4, the balanced splitter 21 described above, can achieve a reduction of an in insertion loss. Furthermore, the balanced splitter 21, which is composed of the six  $1/4$  wavelength strip lines 31 to 36 and the two resistors R1, R2, can be composed by using a smaller number of components as compared with the conventional balanced splitter 1 shown in Fig. 14, thereby making it possible to achieve miniaturization.

#### EMBODIMENT 2 (see Fig. 2)

As shown in Fig. 2, a balanced splitter 41 includes  $1/4$  strip lines 31, 32, 33, 34, 35, 36. Each of the strip lines 31, 32, 33, 34, 35, 36 has one end 31a, 32a, 33a, 34a, 35a, 36a and another end 31b, 32b, 33b, 34b, 35b, 36b, respectively. The one end 31a of the strip line 31 is electrically connected to an unbalanced terminal 22, and the other end 31b thereof is electrically connected to the other end

32b of the strip line 32. The one end 32a of the strip line 32 is grounded. The other end 33b of the strip line 33 is grounded, and the one end 33a thereof is electrically connected to a first balanced terminal 23a. The other end 34b of the strip line 34 is grounded, and the one end 34a thereof is electrically connected to a first balanced terminal 23b. The other end 35b of the strip line 35 is grounded, and the one end 35a thereof is electrically connected to a second balanced terminal 24a. The other end 36b of the strip line 36 is grounded, and the one end 36a thereof is electrically connected to a second balanced terminal 24b.

Further, the one and other ends of each of the strip lines 31, 33 are opposed to each other so that the strip lines 31, 33 become electrically coupled, thereby forming a coupler. Further, the one and other ends of each of the strip lines 32, 34 are opposed to each other so that the strip lines 31, 33 become electrically coupled, thereby forming a coupler.

Likewise, the one and other ends of each of the strip lines 31, 35 are opposed to each other so that the strip lines 31, 33 become electrically coupled, thereby forming a coupler. Further, the one and other ends of each of the strip lines 32, 36 are opposed to each other for electromagnetic coupling, thereby forming a coupler.

The strip lines 31 and 32 are connected in series to form an unbalanced line, the strip lines 33 and 34 form a first balanced line, and the strip lines 35 and 36 form a second balanced line.

Further, resistors R1, R2 are electrically connected between the first balanced terminal 23a and the second balanced terminal 24a, and between the first balanced terminal 23b and the second balanced terminal 24b, respectively. The values of the resistors R1, R2 are each designed to be  $1/2$  of the sum of the balanced line characteristic impedance value of the first balanced terminal 23a, 23b and the balanced line characteristic impedance value of the second balanced

terminal 24a, 24b.

The balanced splitter 41 is an "unbalanced input/balanced output splitter" for splitting a single unbalanced signal into two balanced signals, and provides the same operation/effect as that of the balanced splitter 21 according to EMBODIMENT 1.

EMBODIMENT 3 (see Figs. 3 and 4)

Fig. 3 is an exploded perspective view of a laminated balanced splitter 21A incorporating the balanced splitter 21 shown in Fig. 1. The balanced splitter 21A is composed of dielectric sheets 65 having a ground electrode 51, 52, 53 formed on a surface thereof, dielectric sheets 65 in which a 1/4 strip line 31, 32, 33, 34, 35, 36 and an inter-layer connecting via hole 60 are formed, dielectric sheets 65 in which an extraction electrode 54, 55, 56, 57, 58, 59 and the inter-layer connecting via hole 60 are formed, an outer dielectric sheet 65 with no electrode formed in advance, and the like.

As the material used for the dielectric sheet 65, dielectric ceramic powder kneaded with a binder or the like and formed into a sheet-like configuration is used. The strip lines 31 to 36 and the extraction electrodes 54 to 59 or the like are formed by sputtering, vapor-deposition, printing, or the like, and are each made of a material such as Ag, Ag-Pd, or Cu. The inter-layer connecting via hole 60 is formed by forming a through-hole in the dielectric sheet 65 using a laser beam or the like, and filling this through-hole with a conductive paste consisting of Ag, Ag-Pd, or Cu by print coating or the like.

With respect to the laminating direction of the dielectric sheets 65, the dielectric sheets 65 provided with the ground electrodes 51, 52, 53 are respectively arranged at upper, middle, and lower layer portions. The dielectric sheets arranged with the spiral-shaped strip line 33, 35 sandwich the dielectric sheet arranged with between the ground electrodes 51 and 52.. It should be noted that while in

EMBODIMENT 3 the dielectric sheets provided with the strip lines 33, 31, 35 are arranged in the stated order from the upper layer, the dielectric sheets provided with the strip lines 35, 31, 33 may be arranged in the stated order from the upper layer.

Likewise, the dielectric lines arranged with the spiral-shaped strip lines 34, 36 thereof sandwich the dielectric sheet that arranged with the spiral-shaped strip line 32 thereof and is arranged between the ground electrodes 52 and 53. It should be noted that while in EMBODIMENT 3 the dielectric sheets provided with the strip lines 34, 32, 36 are arranged in the stated order from the upper layer, the dielectric sheets provided with the strip lines 36, 32, 34 may be arranged in the stated order from the upper layer. Further, the dielectric sheets provided with the strip lines 34, 32, 36 may be arranged above the dielectric sheet provided with the ground electrode 52, with the dielectric sheets provided with the strip lines 33, 31, 35 being provided below the dielectric sheet provided with the ground electrode 52.

Each of the ground electrodes 51 to 53 is formed over a large area of the surface of the dielectric sheet 65, with a part thereof being exposed at the center of the rear edge of the sheet 65. The strip line 33 is arranged at the center of the dielectric sheet 65, and one end 33a thereof is exposed at the center of the rear edge of the dielectric sheet 65. The other end 33b of the strip line 33 is extended to the right edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 54 formed at the layer immediately above.

The strip line 31 is arranged at the center of the dielectric sheet 65, and one end 31a thereof is exposed on the right side of the rear edge of the dielectric sheet 65. The other end 31b of the strip line 31 is extended to the center of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the

extraction electrode 55 formed in the layer immediately above. The strip line 35 is arranged at the center of the dielectric sheet 65, and one end 35a thereof is exposed at the center of the rear edge of the dielectric sheet 65. The other end 35b of the strip line 35 is extended to the left edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 56 formed in the layer immediately below.

Further, the one ends 31a, 33a and the other ends 31b, 33b of the strip lines 31, 33 are opposed to each other so that the strip lines 31, 33 become electrically coupled with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 31a, 35a and the other ends 31b, 35b of the strip lines 31, 35 are opposed to each other so that the strip lines 31, 35 become electrically coupled with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

Further, the strip line 34 is arranged at the center of the dielectric sheet 65, and one end 34a thereof is exposed at the center of the rear edge of the dielectric sheet 65. The other end 34b of the strip line 34 is extended to the right side of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 57 formed in the layer immediately above. The strip line 32 is arranged at the center of the dielectric sheet 65, and one end 32a thereof is an open end. The other end 32b of the strip line 32 is extended to the center of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 58 formed in the layer immediately above. The strip line 36 is arranged at the center of the dielectric sheet 65, and one end 36a thereof is exposed at the center of the rear edge of the dielectric sheet 65. The other end 36b of the strip line 36 is extended to the left side of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction

electrode 59 formed in the layer immediately below.

Further, the one ends 32a, 34a and the other ends 32b, 34b of the strip lines 32, 34 are opposed to each other for electromagnetic coupling between the strip lines 32 and 34 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 32a, 36a and the other ends 32b, 36b of the strip lines 32, 36 are opposed to each other so that the strip lines 32, 36 become electrically coupled with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

The dielectric sheets 65 are laminated one another and integrally fired to form a laminate 71 as shown in Fig. 4. A first balanced terminal 23b, a second balanced terminal 24b, and a relay terminal 25 are formed on the right side, on the left side, and at the center, respectively, of the front side surface of the laminate 71, and an unbalanced terminal 22 and a ground terminal G are formed on the right side and at the center, respectively, of the rear side surface thereof. A first balanced terminal 23a is formed in the right side surface of the laminate 71, and a second balanced terminal 24a is formed in the left side surface thereof. Each of the terminals is formed so as to extend from either side surface to the upper and lower surfaces.

The first balanced terminals 23a, 23b are electrically connected to the extraction electrodes 54, 57, respectively. The unbalanced terminal 22 is electrically connected to the one end 31a of the strip line 31, and the relay terminal 25 is electrically connected to the extraction electrodes 55, 58. The second balanced terminals 24a, 24b are electrically connected to the extraction electrodes 56, 59, respectively. The ground terminal G is electrically connected to part of the ground electrodes 51 to 53 and to the one ends 33a, 35a, 34a, 36a of the strip lines 33, 35, 34, 36.

Further, resistors R1, R2 are formed on the upper surface of the laminate 71 by printing a carbon paste or the like. The resistor R1

provides electrical connection between the first balanced terminal 23a and the second balanced terminal 24a, and the resistor R2 provides electrical connection between the first balanced terminal 23b and the second balanced terminal 24b. It should be noted that the resistors R1, R2 may be formed on the bottom surface of the laminate 71.

Further, the resistors R1, R2 may be chip resistors disposed on the surface of the laminate instead of printed resistors. Further, the resistors R1, R2 may be externally mounted to a printed board incorporating the balanced splitter 21A and be connected to the respective terminals through wiring.

The laminated balanced splitter 21A configured as described above allows easy adjustment of the electromagnetic coupling values between the strip lines 31-33, 31-35, 32-34, and 32-36 by changing the thickness of the dielectric sheet 65 or the like. Further, the strip lines 31 to 36 and the like are formed at the same time through the same manufacturing method, thereby making it possible to suppress variations in electromagnetic coupling characteristics occurring during the manufacture.

Further, the strip lines 33, 31, 35 are arranged above the ground electrode 52, and the strip lines 34, 32, 36 are arranged below the ground electrode 52, whereby the strip lines 33, 31, 35 and the strip lines 34, 32, 36 are shielded by the ground electrode 52. Accordingly, there is no electromagnetic coupling between the strip lines 33, 31, 35 and the strip lines 34, 32, 36, thereby making it possible to obtain broadband, low-loss characteristics.

EMBODIMENT 4 (see Figs. 5 and 6)

Fig. 5 is an exploded perspective view of a laminated balanced splitter 21B incorporating the balanced splitter 21 shown in Fig. 1. The balanced splitter 21B is composed of dielectric sheets 65 having a ground electrode 51, 53 formed on a surface thereof, dielectric sheets 65 in which a  $1/4$  strip line 31, 32, 33, 34, 35, 36 and an inter-layer



connecting via hole 60 are formed, dielectric sheets 65 in which an extraction electrode 54, 56, 57, 59 and the inter-layer connecting via hole 60 are formed, a dielectric sheet 65 in which a relay terminal 75 and the inter-layer connecting via hole 60 are formed, and an outer dielectric sheet 65 with no electrode formed in advance, and the like.

With respect to the laminating direction of the dielectric sheets 65, the dielectric sheets 65 provided with the ground electrodes 51, 53 are arranged at upper and lower layer portions, respectively. Between the ground electrodes 51 and 53, there are arranged, across the dielectric sheet provided with the strip lines 31, 32 that are spiral-shaped, the dielectric sheet provided with the strip lines 33, 34 that are also strip-shaped, and the dielectric sheet provided with the strip lines 35, 36 that are also spiral-shaped. It should be noted that while in EMBODIMENT 4 the dielectric sheets provided with the strip lines 33 and 34, 31 and 32, and 35 and 36 are arranged in the stated order from the upper layer, the dielectric sheets provided with the strip lines 35 and 36, 31 and 32, and 33 and 34 may be arranged in the stated order from the upper layer.

The strip lines 33 and 34 are respectively arranged in the right and left halves of the same dielectric sheet 65. Respective one ends 33a, 34a of the strip lines 33, 34 are connected to each other and exposed at the center of the rear edge of the dielectric sheet 65. The other end 33b of the strip line 33 is extended to the right edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 54 formed in the layer immediately above. The other end 34b of the strip line 34 is extended to the right side of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 57 formed in the layer immediately above.

The strip lines 31 and 32 are respectively arranged in the right and left halves of the same dielectric sheet 65. One end 31a of the

strip line 31 is exposed on the right side of the rear edge of the dielectric sheet 65. The other end 31b of the strip line 31 is electrically connected to the other end 32b of the strip line 32 through the inter-layer connecting via hole 60 and the relay electrode 75 formed in the layer immediately above. One end 32a of the strip line 32 is an open end.

Further, the one ends 31a, 33a and the other ends 31b, 33b of the strip lines 31, 33 are opposed to each other for electromagnetic coupling between the strip lines 31 and 33 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 32a, 34a and the other ends 32b, 34b of the strip lines 32, 34 are opposed to each other for electromagnetic coupling between the strip lines 32 and 34 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

The strip lines 35 and 36 are respectively arranged in the right and left halves of the same dielectric sheet 65. Respective one ends 35a, 36a of the strip lines 35, 36 are connected to each other and exposed at the center of the rear edge of the dielectric sheet 65. The other end 35b of the strip line 35 is extended to the left edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 56 formed in the layer immediately below. The other end 36b of the strip line 36 is extended to the left side of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 59 formed in the layer immediately below.

Further, the one ends 31a, 35a and the other ends 31b, 35b of the strip lines 31, 35 are opposed to each other for electromagnetic coupling between the strip lines 31 and 35 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 32a, 36a and the other ends 32b, 36b of the strip lines 32, 36 are opposed to each other for electromagnetic coupling between

the strip lines 32 and 36 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

The dielectric sheets 65 are laminated on top of one another and integrally fired to form a laminate 71 as shown in Fig. 6. A first balanced terminal 23b, a second balanced terminal 24b, and a relay terminal 25 are formed on the right side, on the left side, and at the center, respectively, of the front side surface of the laminate 71, and an unbalanced terminal 22 and a ground terminal G are formed on the right side and at the center, respectively, of the rear side surface. A first balanced terminal 23a is formed in the right side surface of the laminate 71, and a second balanced terminal 24a is formed in the left side surface thereof. Each of the terminals is formed so as to extend from either side surface to the upper and lower surfaces.

The first balanced terminals 23a, 23b are electrically connected to the extraction terminals 54, 57, respectively. The unbalanced terminal 22 is electrically connected to the one end 31a of the strip line 31. The second balanced terminals 24a, 24b are electrically connected to the extraction electrodes 56, 59, respectively. The ground terminal G is electrically connected to part of the ground electrodes 51, 53 and the one ends 33a, 34a, 35a, 36a of the strip lines 33, 34, 35, 36.

Further, resistors R1, R2 are formed on the upper surface of the laminate 71 by printing a carbon paste or the like. The resistor R1 provides electrical connection between the first balanced terminal 23a and the second balanced terminal 24a, and the resistor R2 provides electrical connection between the first balanced terminal 23b and the second balanced terminal 24b. It should be noted that the resistors R1, R2 may be formed on the bottom surface of the laminate 71. Further, the resistors R1, R2 may be chip resistors disposed on the surface of the laminate instead of printed resistors. Further, the

resistors R1, R2 may be externally mounted to a printed board incorporating the balanced splitter 21A and connected to the respective terminals through wiring.

The laminated balanced splitter 21B configured as described above allows easy adjustment of the electromagnetic coupling values between the strip lines 31-33, 31-35, 32-34, and 32-36 by changing the thickness of the dielectric sheet 65 or the like. Further, the strip lines 31 to 36 and the like are formed at the same time through the same manufacturing method, thereby making it possible to suppress variations in electromagnetic coupling characteristics occurring during the manufacture.

Further, the strip lines 31 and 32, 33 and 34, and 35 and 36 are arranged in the same sheet 65, whereby electromagnetic coupling occurs between the strip lines 31 and 32, 33 and 34, and 35 and 36.

Therefore, narrowband, low-loss characteristics can be obtained.

EMBODIMENT 5 (see Figs. 7 through 10)

There are cases where the laminated balanced splitter 21A, 21B according to EMBODIMENT 3 or EMBODIMENT 4 is used with the resistor R1, R2 being externally mounted to a printer board including the balanced splitter 21A, 21B. In those cases, depending on the wiring pattern on the printed board connecting between the strip line 33, 34, 35, 36 and the resistor R1, R2, a delay may occur in the phase of the signal, resulting in a decrease in isolation between the first balanced terminal 23a, 23b and the second balanced terminal 24a, 24b.

A laminated balanced splitter according to EMBODIMENT 5 is designed to overcome this problem. A laminated balanced splitter 21C shown in Figs. 7 and 8 represents an improvement over the balanced splitter 21A according to EMBODIMENT 3. Further, a laminated balanced splitter 21D shown in Figs. 9 and 10 represents an improvement over the balanced splitter 21B according to EMBODIMENT 4.

The laminated balanced splitter 21C, 21D has, in the dielectric

sheet 65 provided with the extraction electrode 54, a resistor-connecting-terminal extracting electrode 80 formed in a state of electrically connected to the extraction electrode 54, and has a resistor connecting terminal 26, which is electrically connected to the resistor-connecting-terminal extracting electrode 80, formed on the left side of the rear side surface of the laminate 71.

The resistor connecting terminal 26 serves to connect the resistor R1 and is arranged between the unbalanced terminal 22 and the second balanced terminal 24a. Further, the resistor-connecting-terminal extracting electrode 80 provides electrical connection between: the extraction electrode 54 of the strip line 33, which is connected to, from among the first balanced terminals 23a, 23b, the first balanced terminal 23 that is not adjacent to the second balanced terminals 24a, 24b; and the resistor connecting terminal 26, which is provided at a position where it straddles the unbalanced terminal 22. It should be noted that in the case where the extraction electrode 56 of the strip line 35 is connected to the first balanced terminal 23a, the resistor-connecting-terminal extracting electrode 80 provides electrical connection between the extraction electrode 56 and the resistor connecting terminal 26.

As described above, with the provision of the resistor connecting terminal 26 and the resistor-connecting-terminal extracting electrode 80, a delay in signal phase due to the wiring pattern on the printed board can be suppressed to a minimum, thereby making it possible to suppress a reduction in isolation between the first balanced terminal 23a, 23b and the second balanced terminal 24a, 24b.

While in EMBODIMENT 5 the resistor connecting terminal 26 is arranged between the unbalanced terminal 22 and the second balanced terminal 24a, the resistor connecting terminal 26 may be arranged between the unbalanced terminal 22 and the first balanced terminal 23a. In this case, one of the extraction electrode 57 of the strip line 34

and the extraction electrode 59 of the strip line 36, and the resistor connecting terminal 26 are electrically connected to each other through the resistor-connecting-terminal extracting electrode 80.

It should be noted that a decrease in isolation between the first balanced terminal 23a, 23b and the second balanced terminal 24a, 24b can also be suppressed, without the provision of the resistor connecting terminal 26, by printing the resistors R1, R2 onto the surface of the laminate 71 as described in EMBODIMENTS 3 and 4 or by mounting them to the laminate 71 as chip components.

EMBODIMENT 6 (see Figs. 11 and 12)

Fig. 11 is an exploded perspective view of a laminated balanced splitter 41A incorporating the balanced splitter 41 shown in Fig. 2. The balanced splitter 41A is composed of dielectric sheets 65 having a ground electrode 51, 52, 53 formed on a surface thereof, dielectric sheets 65 in which a 1/4 strip line 31, 32, 33, 34, 35, 36 and an inter-layer connecting via hole 60 are formed, dielectric sheets 65 in which an extraction electrode 54, 55, 56, 57, 58, 59 and the inter-layer connecting via hole 60 are formed, and an outer dielectric sheet 65 with no electrode formed in advance, and the like.

The ground electrodes 51 to 53 are each formed over a large area of the surface of the dielectric sheet 65, and partially exposed at the center of the rear edge of the sheet 65. The strip line 33 is arranged at the center of the dielectric sheet 65, and one end 33a thereof is exposed at the right edge of the dielectric sheet 65. The other end 33b of the strip line 33 is extended to the center of the rear edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 54 formed in the layer immediately above.

The strip line 31 is arranged at the center of the dielectric sheet 65, and one end 31a thereof is exposed on the right side of the rear edge of the dielectric sheet 65. The other end 31b of the strip

line 31 is extended to the center of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 55 formed in the layer immediately above. The strip line 35 is arranged at the center of the dielectric sheet 65, and one end 35a thereof is exposed at the left edge of the dielectric sheet 65. The other end 35b of the strip line 35 is extended to the center of the rear edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 56 formed in the layer immediately below.

Further, the one ends 31a, 33a and the other ends 31b, 33b of the strip lines 31, 33 are opposed to each other for electromagnetic coupling between the strip lines 31 and 33 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 31a, 35a and the other ends 31b, 35b of the strip lines 31, 35 are opposed to each other so that the strip lines 31, 35 become electrically coupled with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

Further, the strip line 34 is arranged at the center of the dielectric sheet 65, and one end 34a thereof is exposed on the right side of the front edge of the dielectric sheet 65. The other end 34b of the strip line 34 is extended to the center of the rear edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 57 formed in the layer immediately above. The strip line 32 is arranged at the center of the dielectric sheet 65, and one end 32a thereof is an open end. The other end 32b of the strip line 32 is extended to the center of the front edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 58 formed in the layer immediately above. The strip line 36 is arranged at the center of the dielectric sheet 65, and one end 36a thereof is exposed on the right side of the front edge of the dielectric sheet 65. The other end 36b of the strip line 36 is

extended to the center of the rear edge of the dielectric sheet 65 through the inter-layer connecting via hole 60 and the extraction electrode 59 formed in the layer immediately below.

Further, the one ends 32a, 34a and the other ends 32b, 34b of the strip lines 32, 34 are opposed to each other for electromagnetic coupling between the strip lines 32 and 34 with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler. Likewise, the one ends 32a, 36a and the other ends 32b, 36b of the strip lines 32, 36 are opposed to each other so that the strip lines 32, 36 become electrically coupled with the dielectric sheet 65 being sandwiched therebetween, thereby forming a coupler.

The dielectric sheets 65 are laminated one another and integrally fired to form a laminate 71 as shown in Fig. 12. A first balanced terminal 23b, a second balanced terminal 24b, and a relay terminal 25 are formed on the right side, on the left side, and at the center, respectively, of the front side surface of the laminate 71, and an unbalanced terminal 22 and a ground terminal G are formed on the right side and at the center, respectively, of the rear side surface thereof. A first balanced terminal 23a is formed in the right side surface of the laminate 71, and a second balanced terminal 24a is formed in the left side surface thereof. Each of the terminals is formed so as to extend from either side surface to the upper and lower surfaces.

The first balanced terminals 23a, 23b are electrically connected to the one ends 33a, 34a of the strip lines 33, 34, respectively. The unbalanced terminal 22 is electrically connected to the one end 31a of the strip line 31, and the relay terminal 25 is electrically connected to the extraction electrodes 55, 58. The second balanced terminals 24a, 24b are electrically connected to the one ends 35a, 36a of the strip lines 35, 36, respectively. The ground terminal G is electrically connected to part of the ground electrodes 51 to 53 and to the extraction electrodes 54, 56, 57, 59.



Further, resistors R1, R2 are formed on the upper surface of the laminate 71 by printing a carbon paste or the like. The resistor R1 provides electrical connection between the first balanced terminal 23a and the second balanced terminal 24a, and the resistor R2 provides electrical connection between the first balanced terminal 23b and the second balanced terminal 24b. It should be noted that the resistors R1, R2 may be formed on the bottom surface of the laminate 71. Further, the resistors R1, R2 may be chip resistors disposed on the surface of the laminate instead of printed resistors. Further, the resistors R1, R2 may be externally mounted to a printed board incorporating the balanced splitter 41A and be connected to the respective terminals through wiring.

The laminated balanced splitter 41A configured as described above provides the same effect as that of EMBODIMENT 3.

#### OTHER EMBODIMENTS

It should be noted that the present invention is not limited to the embodiments described above but may accommodate various modifications within the scope of the gist of the present invention. In particular, the shape of the strip lines 31 to 36 is arbitrary and may be liner, spiral or serpentine. Further, the strip lines 31 to 36 may not necessarily be set to a length equal to or smaller than the  $1/4$  wavelength.

Further, while in the above-described embodiments the dielectric sheets having the strip lines and the like formed thereon are integrally fired after being laminated on top of one another, this should not be construed restrictively; the sheets used may be fired in advance. Further, the laminated balanced splitter may be fabricated by the fabrication method as described below. That is, after forming a dielectric sheet by coating a paste-like dielectric material by printing or other such method, a paste-like conductive material is coated onto the surface of the dielectric layer to thereby form a

strip line or electrode of an arbitrary shape. Then, the paste-like dielectric material is coated from above the strip line or the like. Through such successive recoatings, a balanced splitter having a laminated structure can be obtained.

#### Industrial Applicability

As described above, the present invention is useful when applied to a balanced splitter of a mobile communication device or the like, and proves particularly advantageous in that it is simple in circuit configuration and enables miniaturization.